Space Weather Technical Forecast

Issued on Monday, 29 January 2024 at 12:56 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Increased Chance of R1/R2 Radio Blackouts. Possible glance from CME and Chance of G1 midweek UTC. Ongoing S1.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity, as measured by GOES16, rose sharply to Moderate in the past 24 hours, with previously subdued occasional C-class activity showing an increased cadence and amplitude to culminate in an M6.8 from AR3559 at 29/0438UTC. This was a long-period flare and was accompanied by an energetic Coronal Mass Ejection (CME), an EUV wave and marked coronal dimming, as well as a Type II radio burst. Early analyses of the ejecta imply that the 512km/s Type II may represent a harmonic, with speeds nearer 1000km/s preferred from analyses. This CME showed a partial halo shock, however the main thrust of the CME is expected to pass west of the Earth, crossing 1AU early in the UTC day of Wednesday 31 January.

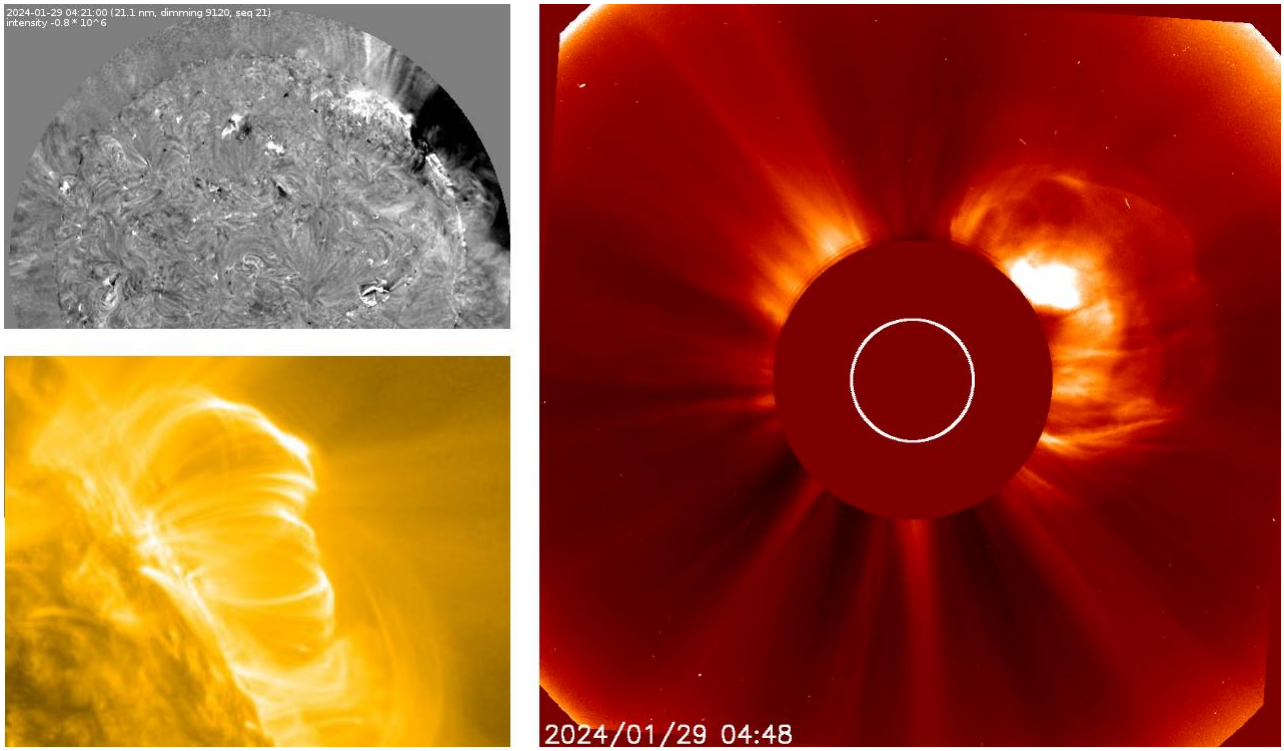

Figure 0: Selected imagery from the M6.8 flare from AR3559 at 29/0438UTC: clockwise from top left: SIDC ROB time integrated dimming in AIA211; Lasco C2 showing CME envelope and AIA171 post-eruptive arcade.

The above sunspot region was one of up to five on the current Earth-facing disc. Because most of the current regions now lie near the solar horizons, monitoring ability is more limited, however strong growth in the leading spots of AR3559 was observed in the current UTC morning, with a

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significant span of 20 degrees solar longitude still identifiable, along with a probable continuation of at least Fko Zurich complexity. The most significant active regions of the remainder of the front side were a new arriving region in the far northeast, which appears bright in EUV and magnetically bipolar, as well as AR3565 to its south, which, although small is showing a propensity toward mainly comprising a Mt Wilson delta spot - something that will be monitored.

No filament eruptions were noted on imagery in the period, although a second Type II radio burst was linked with an event on the arriving eastern horizon at 29/1021UTC, perhaps a sign of an active region here. By far the largest event on coronagraphs then, was the M6.8-tied CME from AR3559. Imagery for the event has been good, although its northern extent on Lasco C3 has been slightly hidden by propagation along the line of the mirror/occulting disc mount for C3. Some influence from the shock is likely on Wednesday 31 January, see the 'Geomagnetic Storms' section for further discussion.

Solar Wind / Geomagnetic Activity: Solar winds, as measured by DSCOVR and ACE at L1 showed a probable emerging weak fast wind regime as of the start of the current reporting period (i.e. around 28/1200UTC). The cause of this enhancement is unclear - given the resolutely negative phi angle (towards the Sun) the source may either be CH95, which is perhaps at too high a solar latitude but a more suitable solar longitude; or else CH94, which is expected to influence Earth, but is perhaps a little early for its westerly coordinates on the disc. This has corollaries for the forecast discussed in the 'Geomagnetic Storms' section.

The solar wind rose from background levels near 375km/s to start the 24 hours to reach a peak nearer 475 in the current UTC day. The solar wind density trace was less clear - with ACE showing a lasting fall within Background levels (single figures ppcc), whereas DSCOVR showed a period of rise within the 'fast wind' after an initial drop off - although still staying within Background levels. The IMF was greatest to start the period at 11nT, with the north-south component varying between +7 and -6nT, with an erratic character.

The net result of the above solar wind measures was for provisionally Quiet to Unsettled geomagnetic indices, peaking with a '3o' in the 21-24UTC interval.

Energetic Particles / Solar Radiation: GOES18 high energy (greater than 10MeV) proton flux showed a sharp and almost immediate rise across all measured energies in the wake of the M6.8 flare, with 10MeV peaking and subsequently plateauing at 33pfu around 29/1200UTC, while 100MeV has thus far risen to 0.6pfu. This implies a relatively direct connection to Earth at present, as also hinted at by the 'snow' observed on Lasco imagery following the event.

GOES16 high energy (greater than 2MeV) electron flux was at Normal Background. The associated 24-hour fluence was well below the Active (1e8 integrated pfu) threshold on a generally steady trend. At 29/0001UTC the 24-hour integrated fluence observation was 1.16e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: There is now an increased daily Chance of M-class flares and a Slight Chance of X-class flares as a result of increased activity in AR3559. This risk may show a step-change downwards around midweek UTC as this region departs.

Solar Wind / Geomagnetic Activity: There is a Slight Chance of G1 from a possibly inbound fast wind enhancement in the first 36 hours of the forecast, although this is now lowered relative to recent guidance for possibly already being in course. There then follows a peak risk of G1 for the period due to the 29/0438UTC M6.8-tied CME, the associated shock passes 1AU early in the UTC day of Wednesday 31 January and offers a peak Chance of G1 as a result.

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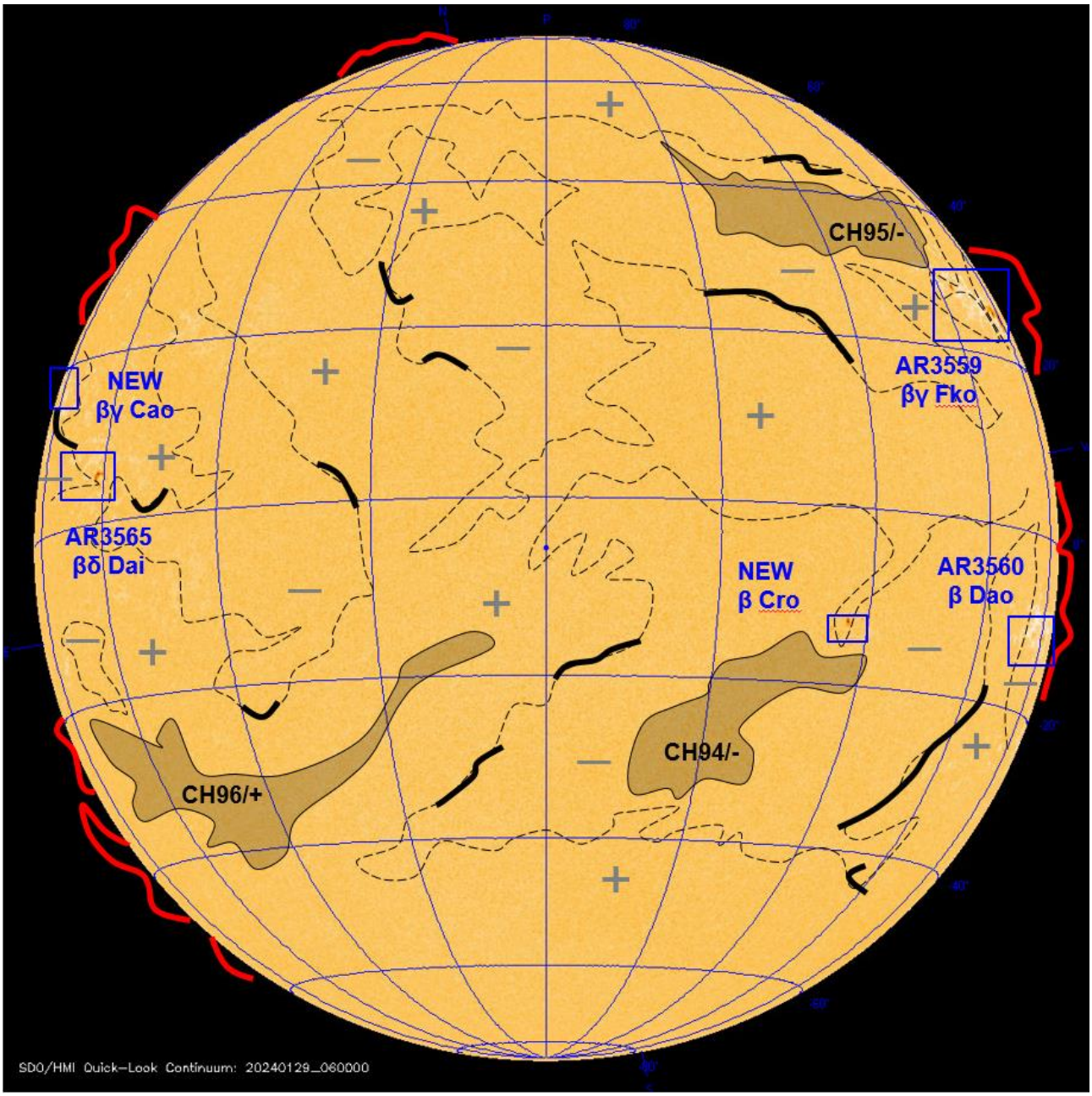
Met Office Space Weather Technical Forecast

Energetic Particles / Solar Radiation: High energy proton flux is Expected to remain above S1 in the immediate term, with a decreasing Chance then following through the first half of the UTC working week as levels wane. The residual risk is then slightly higher than previously advertised for later in the UTC week given this precedent for activity, albeit by then starting to decrease as AR3559 will be - by then - rotating away from a geoeffective position.

The high energy electron flux (greater than 2MeV) is relatively low confidence for a lack of certainty surrounding the current fast wind's source, however exceedence of Active is still deemed unlikely throughout.

Figure 1. Solar Analysis Valid 29/0600UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

There is now one CME that may interact with Earth in the period - that from the M6.8 from AR3559 at 29/0438UTC. Early MOSWOC Enlil modelling of this feature is now available, and suggests the main bulk of the ejecta will pass west of the Sun-Earth line early in the UTC day of Wednesday 31 January. having said this, the shock clearly shows a partial halo component, and further runs may be conducted to ascertain the timing of any influence from this. As things stand, the CME crosses 1AU ahead of Earth around 31/0600UTC, and even the modelled core carries some ensemble members with faint glances from the side lobes. With the caveat that further analyses are to be conducted, there is perhaps a Chance of G1 Minor Storm, probably contained within the UTC day of 31 January. MOSWOC Enlil's initialised solar wind speed is currently slightly in error - nearer 550 rather than the observed 475km/s, which should serve to move any CME arrival later and therefore more wholly contained within that UTC day (31 January).

The fast wind component of the forecast is now of lower confidence. Current solar wind conditions are perhaps most likely indicative of a minor fast wind, although there are two possible sources for this. As stated, CH95 is at a more likely solar longitude but is perhaps too far north to feature; while CH94 is more equatorial but marginal for being westward enough to feature. If the source is the former, there remains a Chance of G1 in the next 36 hours from CH94; if the latter, the probabilities are much lower.

All considered, the chances of G1 have been reduced due to any early-week fast wind perhaps already having shown its hand. The peak risk of geomagnetic activity is now perhaps midweek from the 29/0438UTC CME, although this forecast is subject to change with further modelling.

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	No	10	10	50	1
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
29/0753	Partial	AR3559	NW, near limb	1150km/s	On or after 31/0600UTC	Shock likely intersects Sun-Earth line, main bulk of ejecta misses.

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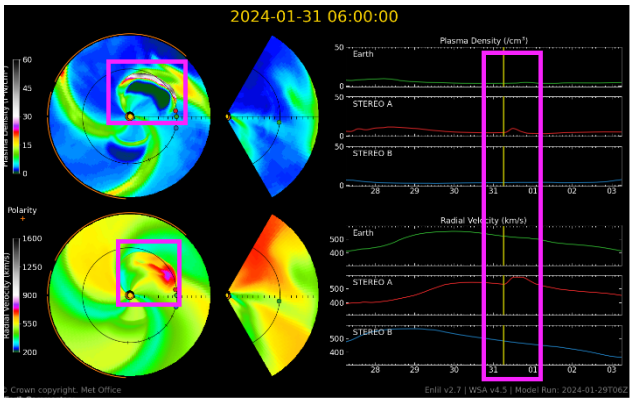
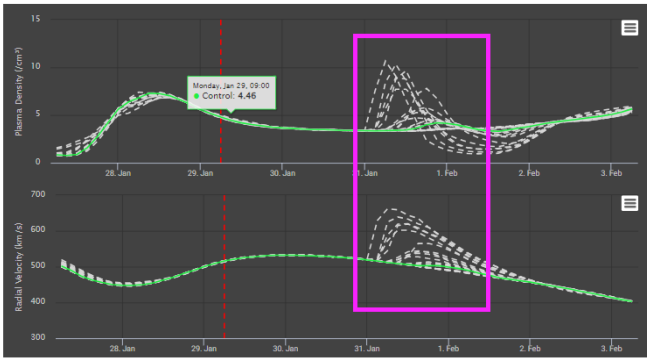
Figure 2: Latest MOSWOC Enlil run and ensemble (badge time 29/0600UTC) showing the simulation paused around the time of the 29/0438UTC CME crossing 1AU. Note that although the deterministic run remains unperturbed, a minority of ensemble members do show degrees of glancing incidence, and this is without explicitly modelling the enveloping shock. Also of note is Enlil's overly-fast intervening modelled wind, which implies the CME may arrive very slightly later than shown, although this is not the dominant source of uncertainty and the effect ought to be small given the fast emission speed.





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Radio Blackouts - X-Ray Flares:

While the current disc is currently presenting a relatively sparse face, there are a number of complex regions that are occupying both limbs. The now unavoidable limb foreshortening effects are hampering analyses, especially in AR3559, which also suffers for being so far north on the disc at a time when Earth is well south of the solar equatorial plane. This region currently appears 'open' in terms of its Zurich classification, however the intense plage may harbour many small spots and perhaps a Mt Wilson delta inferring from its recent burst of activity in delivering an R1 and R2.

The chances of further M-class activity have been revised upwards from the raw disc values slightly, although still only rated at a daily 'Chance' given the uncertainty as to whether the M6.8 from AR3559 was its swansong or a signal of its continued threat. Whatever the risk from this region, its position on the disc should mean that this group leaves by midweek UTC.

The balance of active regions on the facing side is expected to be fairly constant in number but probably not potency, with the departure of AR3559 and AR3560 expected by midweek, and with AR3559's capability unlikely to be matched by any east limb arrivals, with a step-wise decrease then suggested. One of these arriving regions is now showing as flux looping near N20E080, and appears relatively bright in EUV and at least magnetically bipolar. As stated though, overall a decreasing risk of significant flares is suggested, with any revision awaiting east limb arrivals for full analysis.

X Ray Flares	**Level**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability			**(%)**	**(%)**	**(%)**	**(%)**
Active	**R1-R2 M Class**	Yes	50	50	40	30
Very Active	**R3 to R5 X Class**	No	10	10	5	1

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Figure 3: 24-hour HMIIF helioveiwer.org-derived difference imagery to 29/1100UTC, showing a relatively dynamic leading spot group of AR3559, even if the contained details are less apparent as a result of the narrowing viewing angle. White footprint is 28/1100UTC, black 29/1100UTC.

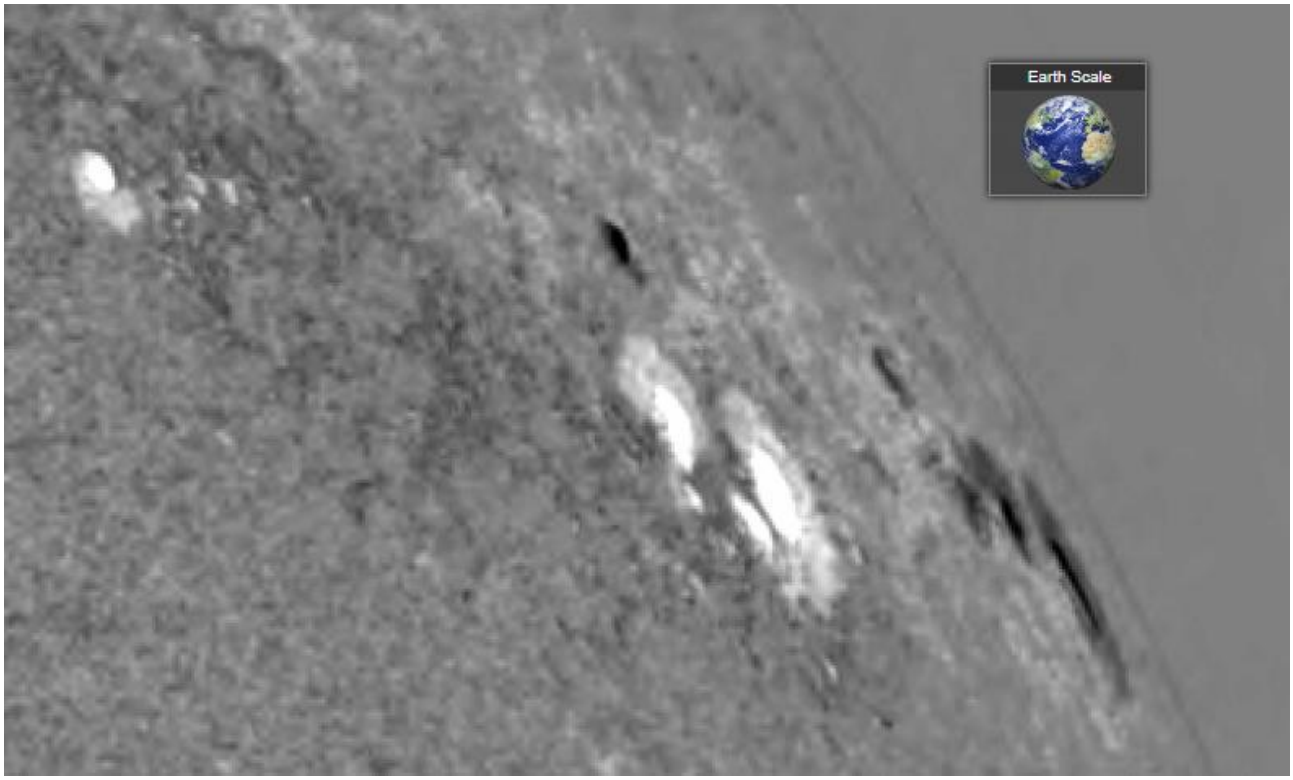

Figure 4: SIDC ROB processed sources of C-class flares and above (from PROBA2) in the 24 hours prior to 29/1100UTC, showing a limbward disrtibution. The region in the northeast may well yet prove to be an active source of flares.

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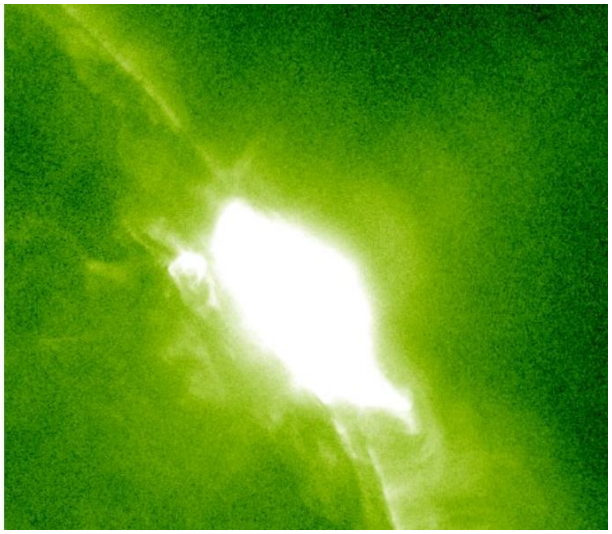
Solar Radiation Storms - (High Energy Protons):

GOES18 high energy (greater than 10MeV) proton flux showed a hard spectral response to the 29/0438UTC M6.8 flare from AR3559, with very little transit delay to L1 and Earth. All measured energies showed an uptick and plateau, however it remains to be seen whether this is the full extent of this event or whether a further resurgence is due.

The evolution from here depends on how many further suitable flares might be produced, with it unclear as to whether AR3559 has now neutralised itself or if there remains significant instability and a risk of further proton-producing flares. The risks of S-scale events have been revised sharply upwards to accommodate given current counts, with a higher level of surviving risk than in previous guidance given this precedent.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	Yes	100	50	25	10
Very Active	**≥ S3 ***	No	5	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 5: Past 24 hours in GOES18 proton flux; the driving GOES16-recorded M6.8 X-ray flare and AIA094 imagery at the time of the flare. Note the almost immediate and hard spectral response to the flare and sustained levels thereafter.



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High Energy Electrons Event (≥ 2MeV):

High energy electron flux (greater than 2MeV) has spent the whole of the past 27-day rotation below High levels, with a notable absence of significant drivers to alter this state in a lack of potent coronal hole fast winds. The recently observed negative-polarity solar wind enhancement is most likely either due to CH94 or perhaps even CH95, although the latter is at a high solar latitude for any Earth effects.

This has important effects regarding the electron forecast, as the most likely driver of eventual Active 24-hour fluence would be CH94/-, so if this feature is still outstanding a rise is more likely than if it has already shown its underwhelming hand at a peak potency of 450km/s.

This lowers confidence in the forecast somewhat, however there is a very slight rise through the four days as a result. MOSWOC REFM's 72-hour projections and persistence values both imply a continuation of the current quiet state, and this is the preferred forecast even with the possibility of a strengthened and awaited CH94.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^{8}$**	No	1	1	5	5
Very Active	**≥ 2 MeV ≥ $1x10^{9}$**	No	1	1	1	1

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